1267029

PATENT SPECIFICATION (11) 1267029

DRAWINGS ATTACHED

(21) Application No. 44020/70 (22) Filed 15 Sept. 1970

(31) Convention Application No. 6914205 (32) Filed 18 Sept. 1969 in

(33) Netherlands (NL)

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H1D 17D 38 7D

(54) FIELD EMISSION CATHODE

(71) We, PHILLIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus

ERRATUM

SPECIFICATION No. 1,267,029

Page 1, line 1, *for* PHILLIPS *read* PHILIPS

THE PATENT OFFICE
21st August 1972

metallised on one side and having a metal grid preferably pressed into the other side thereof. Emission current therefrom is assumed to consist of electrons which move from the interior of the aluminium oxide to the apertures in the metal grid and there either are themselves emitted or liberate secondary electrons from the edges of the grid. Once the emission has started, it is not necessary to apply an external potential difference between the metallisation and the grid, since a suitable potential difference is automatically maintained as a result of the emission. However, this is true only if the cathode goes on supplying current. In so far as is known, this cathode has not resulted in practical applications and data on the achievable emission density and the applied voltages required are not known.

French Patent Specification 1,359,344 discloses a cold cathode which consists of an aluminium plate on which a layer of aluminium oxide 100 to 300 Å thick is formed by vapour-deposition or by anodic oxidation. A layer of metal, such as gold, platinum or palladium, is vapour-deposited on the aluminium oxide, the metal layer being covered in turn with a thick porous layer of magnesium oxide, again by vapour-deposition. The thickness of this last layer is in the order of 50μm. The cathode requires an operating voltage of approximately 10 volts across the layer of aluminium oxide.

French Patent Specification 844,616 discloses a cathode comprising a layer of material having a low work function, such as an alkali

are not known.

It is an object of the invention to provide a field emission cathode having a simple and rigid construction.

The invention provides a field emission cathode comprising a porous layer of aluminium oxide two μm to fifty μm thick formed on an aluminium support by anodic oxidation thereof, and a metal grid contacting the free surface of said layer.

It has long been known (see, e.g., A. J. Dekker and W.Ch. van Geel, Phillips Research Reports *2*, 313—319, 1947) that porous aluminium oxide layers manufactured in this way usually have a substantially hexagonal structure in which cavities and pillar-like particles of aluminium oxide, both having diameters of a few hundred Å and being directed at right angles to the support, seem to alternate. The cavities and pillars of oxide are separated from the underlying aluminium by a closed layer of aluminium oxide the thickness of which, when expressed in tens of Å, is approximately numerically equal to the voltage applied during the electrolytic formation of the layer. This thickness may be between 100 Å and 500 Å in a cathode according to the invention. Oxalic acid or another acid in which the formation of aluminium oxide exclusively occurs should be used as an electrolyte in the formation of the layer.

The thickness of the porous oxide layer is made the specified amount because the

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(54) FIELD EMISSION CATHODE

(71) We, PHILLIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

THIS INVENTION relates to a field emission cathode comprising a layer of aluminium oxide, on one side of which is a conductive metal layer and on the other side of which is a metal grid.

German Patent Specification 746,016 discloses a cathode consisting of a layer of a thick sintered mass of aluminium oxide, metallised on one side and having a metal grid preferably pressed into the other side thereof. Emission current therefrom is assumed to consist of electrons which move from the interior of the aluminium oxide to the apertures in the metal grid and there either are themselves emitted or liberate secondary electrons from the edges of the grid. Once the emission has started, it is not necessary to apply an external potential difference between the metallisation and the grid, since a suitable potential difference is automatically maintained as a result of the emission. However, this is true only if the cathode goes on supplying current. In so far as is known, this cathode has not resulted in practical applications and data on the achievable emission density and the applied voltages required are not known.

French Patent Specification 1,359,344 discloses a cold cathode which consists of an aluminium plate on which a layer of aluminium oxide 100 to 300 Å thick is formed by vapour-deposition or by anodic oxidation. A layer of metal, such as gold, platinum or palladium, is vapour-deposited on the aluminium oxide, the metal layer being covered in turn with a thick porous layer of magnesium oxide, again by vapour-deposition. The thickness of this last layer is in the order of 50μm. The cathode requires an operating voltage of approximately 10 volts across the layer of aluminium oxide.

French Patent Specification 844,616 discloses a cathode comprising a layer of material having a low work function, such as an alkali metal or alkaline earth. This layer is present between a thin aluminium oxide layer and a support. The aluminium oxide is covered by a gauze, or by a very thin metal layer which is permeable to electrons. With approximately 1 volt across the aluminium oxide, emission currents in the order of 1 A are said to have been reached. In order to stimulate the emission it is said that the cathode can be slightly heated or be exposed to infrared radiation. The field emission occurring in this cathode is said to be obtained at field strengths of 10^4 V/cm, a factor 100 to 1000 lower than normal. Practical applications of this cathode are not known.

It is an object of the invention to provide a field emission cathode having a simple and rigid construction.

The invention provides a field emission cathode comprising a porous layer of aluminium oxide two μm to fifty μm thick formed on an aluminium support by anodic oxidation thereof, and a metal grid contacting the free surface of said layer.

It has long been known (see, e.g., A. J. Dekker and W.Ch. van Geel, Phillips Research Reports *2*, 313—319, 1947) that porous aluminium oxide layers manufactured in this way usually have a substantially hexagonal structure in which cavities and pillar-like particles of aluminium oxide, both having diameters of a few hundred Å and being directed at right angles to the support, seem to alternate. The cavities and pillars of oxide are separated from the underlying aluminium by a closed layer of aluminium oxide the thickness of which, when expressed in tens of Å, is approximately numerically equal to the voltage applied during the electrolytic formation of the layer. This thickness may be between 100 Å and 500 Å in a cathode according to the invention. Oxalic acid or another acid in which the formation of aluminium oxide exclusively occurs should be used as an electrolyte in the formation of the layer.

The thickness of the porous oxide layer is made the specified amount because the

required potential difference across the layer will usually be in the order of 50 volts or higher. This, in conjunction with the specified layer thickness enables the metal grid to be made very thin, e.g. it may be made of wires only 50 μm thick or less, the grid being attracted by the electrostatic force over the whole surface of the cathode. The advantage of this as compared with a more rigid grid of thicker wires which is held only by mechanical force is that it can engage the surface of the oxide layer better, which is conducive to uniformity of the emision across the whole surface.

In order that the invention may be readily carried into effect, an embodiment will now be described in greater detail, by way of example, with reference to the accompanying diagrammatic drawing, in which:

Figure 1 is a representation on an exaggerated scale of the electrode system of an electric discharge tube together with the associated electric connections and Figure 2 shows some current-voltage characteristics.

In Figure 1 an evacuated electric discharge envelope (not shown) contains a strip 1 of aluminium which has two right angled bends and an upper surface area of 0.3 sq. cm. A porous aluminium oxide layer 2, two μm to fifty μm, for exmple 5 μm thick, and in which cavities are present at right angles to its surface, is present on the aluminium strip, the cavities and the intermediate oxide having transverse dimensions of from 200 to 500 Å. Below said layer is a layer of aluminium oxide between 100 Å and 500 Å, for example about 100 Å, thick. A copper gauze 3, having a 40 μm mesh wire thickness of 7 μm, contacts the free surface of the aluminium oxide 2. A nickel plate anode 4 is at a distance of 2 mm from the gauze 3. The electric connections to the aluminium strip, the gauze and the nickel anode are denoted by 5, 6 and 7 respectively. Current limiting resistors 8 and 9, each of 1M Ω, are included in the connections 5 and 7.

In Figure 2 the potential difference in volts (applied by means not shown) between the connectors 6 and 7 in volts is plotted on the horizontal axis, and the resulting electron current in μA which flows to the anode 4 is plotted on the vertical axis. Curve A is for the case in which the voltage between 5 and 6 is 120 volts (applied by means not shown) and curve B is for the case in which said voltage is 180 volts. The resulting potential differences (greater than 50V) between 1 and 3 are sufficient to hold the gauze 3 against the oxide 2. The currents between 5 and 6 are 2.0 and 12.5 μA, respectively.

WHAT WE CLAIM IS:—

1. A field emission cathode comprising a porous layer of aluminium oxide two μm to fifty μm thick formed on an aluminium support by anodic oxidation thereof, and a metal grid contacting the free surface of said layer.

2. A cathode as claimed in Claim 1, including means for applying a positive potential to said grid relative to said support.

3. A cathode as claimed in Claim 2, wherein the potential is sufficiently large to hold the metal grid against the aluminium oxide layer by the resulting electrostatic force.

4. A cathode as claimed in Claim 2 or 3, wherein the potential is more than 50 volt.

5. A cathode as claimed in Claim 1, 2, 3 or 4, wherein the porous aluminium oxide layer has a hexagonal structure in which cavities extending at right angles to the support alternate with intermediate material, both with transverse dimensions of between 200 Å and 500 Å, the cavities and the intermediate material being separated from the underlying support by a closed layer of aluminium oxide between 100 Å and 500 Å thick.

6. A field emission cathode substantially as herein described with reference to the accompanying drawing.

7. An electric discharge tube including a field emission cathode as claimed in any preceding Claim.

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1267029 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

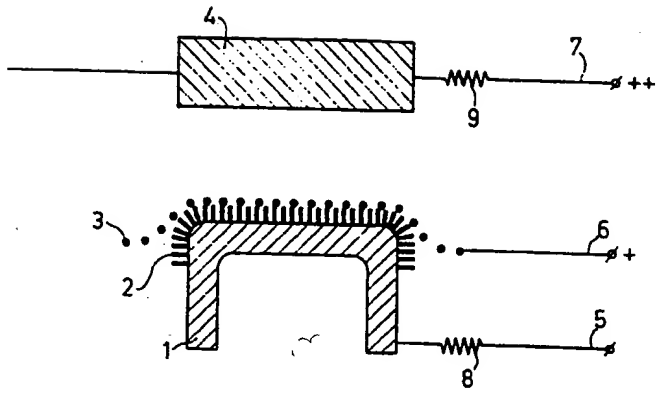

Fig.1

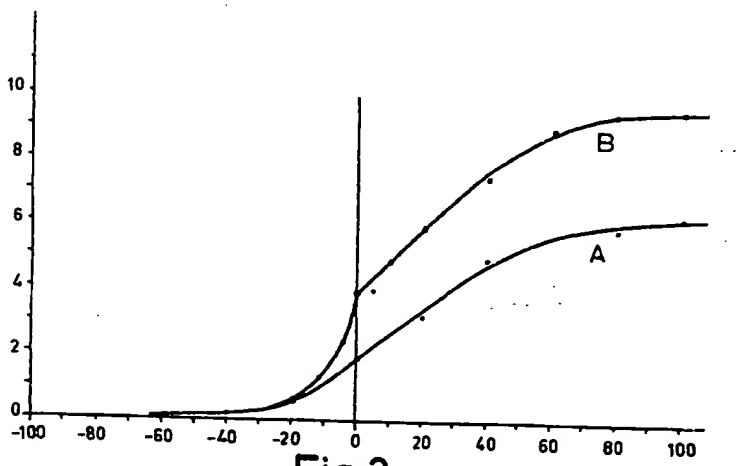

Fig.2